Reconstructive Surgery in the Thermally Injured Patient

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KEYWORDS

- Microvascular free-tissue transfer • Pedicle flaps
- Reconstructive Surgery • Thermal injury • Z-plasties
- Skin grafting

AN INCREASED NEED FOR RECONSTRUCTIVE SURGERY

Reconstruction is a necessity in the complete care of the burn patient. This need has grown not only because of advances made in critical care resulting in improved patient survival, but also because of an increased number of burn admissions. In 2011, the American Burn Association approximated that 450,000 people suffer annually from burn injuries requiring medical treatment.[1] Of these, 45,000 require admission, 55% (24,750 admissions) will enter the 125 hospitals with specialized burn care centers,[2] an increase of 340% from 1995.[3] Among those admitted to these burn centers, the expected overall survival rate is 94.8%.[2] Depending on the depth and location of the burn injury, many of these patients require reconstructive surgery to ameliorate the late effect of burn scarring.

In addition to a greater demand for reconstruction secondary to the number of surviving patients, there has also been an increased awareness by patients and their providers that reconstructive surgery is a possibility. Furthermore, advances in tissue engineering and in surgical techniques have increased the options available to patients who previously might have "unreconstructable" deformities.

BASIC PHILOSOPHIES

The basic goal of all reconstruction is to restore form and function and to restore "like with like"; that is, replace tissue of a certain quality using other tissues of the same or

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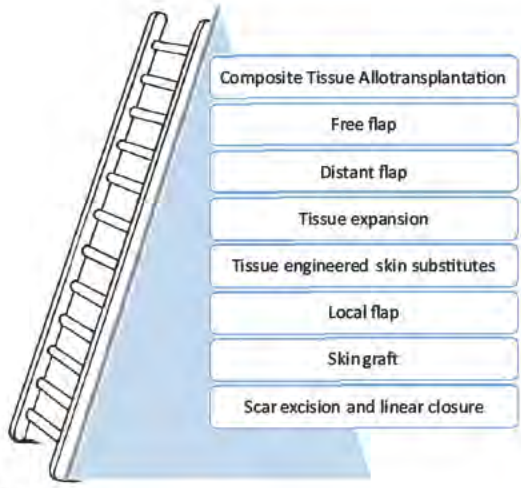

Fig. 1. Reconstructive ladder.

similar quality. Because burn scarring has functional, aesthetic, and psychosocial consequences,[4] burn reconstruction is among the most challenging reconstructive problems faced by plastic surgeons. Local tissues are often insufficient and scarred, vascular supply might have been compromised, and the tissues simply do not possess the normal characteristics we have come to know. Nevertheless, some basic guiding principles exist.

First, an accurate diagnosis of the deformity and an appraisal of the missing parts are essential. This step is particularly challenging in burn reconstruction because there is not often a physical deficit, at least not until an adequate excision or release has been performed. The "reconstructive ladder" (**Fig. 1**) is used as a guideline for the various available options, and often all rungs are needed in the management of severe deformities.[5] Realistic goals must be set from the start as to what might be achievable with the reconstruction. A thorough investigation into the history of the patient—in particular, the operations and flaps that were previously utilized and the available potential donor sites—is mandatory. Finally, it is important to formulate a comprehensive treatment plan based on the diagnosis. This plan is presented to the patient and his or her family with a timetable for reconstruction, emphasizing that the sequences are designed not to burn future bridges and that flexibility is necessary. A good rapport with the patient and his or her family is as important as the reconstructive plan. Rarely are 1 or 2 operations enough to achieve the result that the patient is looking for.

Burn scars change over time. In the first 3 years or even later, scars change in both color and quality. The characteristic redness and swelling of burn scars is more profound than that of traumatic wounds. For this reason, most reconstructive surgeons typically delay the reconstruction until 1 year or longer after the burn's occurrence to allow for inflammation to subside. Earlier reconstruction, although necessary at times, can result in less durable outcomes. Patients are informed that repeat releases might be necessary. However, there are clearly circumstances that dictate earlier surgical interventions, such as correction of ectropion to prevent exposure keratitis or correction of microstomia to improve dental hygiene and nutrition.[6]

Table 1 Theoretic length increases with various Z-plasty angles					
Limb angle	30°	45°	60°	75°	90°
Gain in length (%)	25	50	75	100	120

Created with data from Hove C, Williams E, Rodgers B. Z-plasty: a concise review. Facial Plast Surg 2001;17:289–94.

Burn patients often do not remember their acute or reconstructive operations because of the heavy sedation utilized during much of their acute stay. In contrast, during later reconstructive procedures, not only are they cognizant of the multiple procedures required, but they are also invested in their own care. As a consequence, experienced perioperative burn nurses can be an excellent resource. In addition, even our best patients lose sight of the "big picture" at some point; encouragement from those experienced burn staff should always be seen as part of a curative treatment plan.

COMMON RECONSTRUCTIVE PROBLEMS AND TECHNIQUES

In burn reconstruction, 2 problems are rarely exactly alike. The unique distribution and depth of the thermal insult combined with each person's propensity to scarring makes each problem unique. However, there are some common themes. The head and neck and the extremities bear more than their share of the reconstructive burden. Full-thickness burn to the face and neck results in a stigmata that can include some or all of the following: Lower eyelid ectropion, short nose with ala flaring, short retruded upper lip, lower lip eversion, flat facial features, loss of jaw line definition, and lack of neck extension.[7] In the extremities, axillary, elbow, wrist, and webspace contractures are common. The specific choice of procedure and techniques varies depending on severity of the contracture and donor tissue availability. Some common techniques include Z-plasties, skin grafting, pedicle flaps, and microvascular free-tissue transfer.

Z-Plasty

The technique of a Z-plasty is composed of a central and 2 lateral incisions in a "Z" configuration. The lengths of the 3 limbs and angles formed between the primary and the secondary incisions are typically equal. This geometric rearrangement transforms the orientation and adds length to a contracted scar. Lengthening depends on the angles and configurations used. A classical Z-plasty uses 60° angles, granting a theoretical 75% increase in length (**Table 1**). Wider angles and longer limbs yield greater lengthening but require greater tissue mobility.[6] Flaps with an angle $<45°$, while easing closure, risk flap necrosis owing to decreased blood supply.[8] Typically, a Z-plasty is performed when a burn scar contracture is linear and there is adjacent tissue laxity. An example of multiple Z-plasties performed for release of an axillary contracture is shown in **Fig. 2**.

Full- and Split-Thickness Skin Grafting

As opposed to a Z-plasty, broad contractures often require transverse scar release or excision with tissue interposition. Often, the wound bed is sufficiently vascular after the release that a full-thickness skin graft or a split-thickness skin graft (STSG) can be applied. Although a full-thickness skin graft gives better esthetic appearance, an

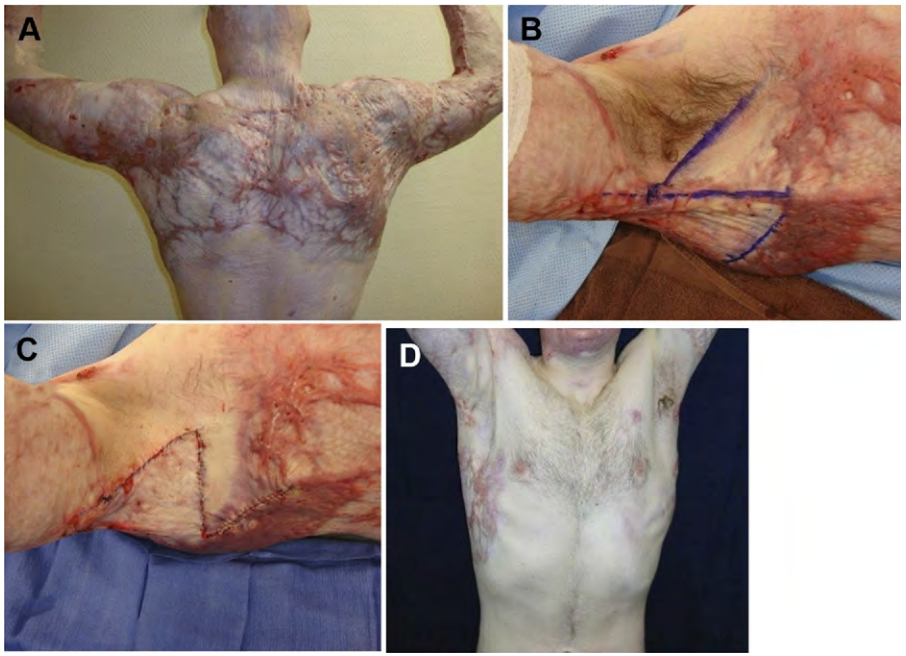

Fig. 2. Example of Z-plasty releases of bilateral axillary contractures. A 30-year-old man with truncal back and axillary burn scar contractures. He is unable to abduct his shoulders more than 90° degrees (*A*), a single Z-plasty was designed on the right (*B*), and 2 serial Z-plasties were designed on the left (not shown). The patient is shown immediately after flap transposition (*C*). Postoperative view is shown with near full abduction on the right and left abduction on the left (*D*).

STSG provides versatility, especially when large areas needing coverage are involved. When considering STSG donor sites, the upper posterolateral thigh is preferred; however, any available, healthy skin can theoretically be used. Consideration should be given to the concealablility of the donor scars as well as accessibility during surgery. In the case of a large burn and minimally available donor skin, options include repeat harvesting, meshing, and use of a dermal regeneration template with STSG. An STSG consists of the epidermis and dermis, typically anywhere from 8th to 16th/1000th of an inch. A thicker STSG can limit repeat harvests and can result in a problematic wound in children, the elderly, or other patients with thin, friable skin. Donor sites can generally be reharvested every 10 to 15 days, barring the presence of infection and depending on the initial depth. Disadvantages to the STSG correlate to its minimal dermal structure and include the tendency for recurrent contractures. full-thickness skin graft s are usually reserved for reconstructions with functional (hands or neck) or aesthetic (eyelids, perioral) areas. The required donor site must have redundant skin; and typically the supraclavicular, lateral thoracic, lower abdominal, or groin areas are chosen. Since harvesting includes removal of all regenerative dermal layers down to adipose tissue, the donor site should ideally retain enough laxity for a primary closure. Although an FTSG provides more cutaneous biology and generally better aesthetics, the graft survival rate is lower than for an STSG; and wound preparation is paramount.[9] An example of broad back contracture released by using an STSG is shown **Fig. 3**.

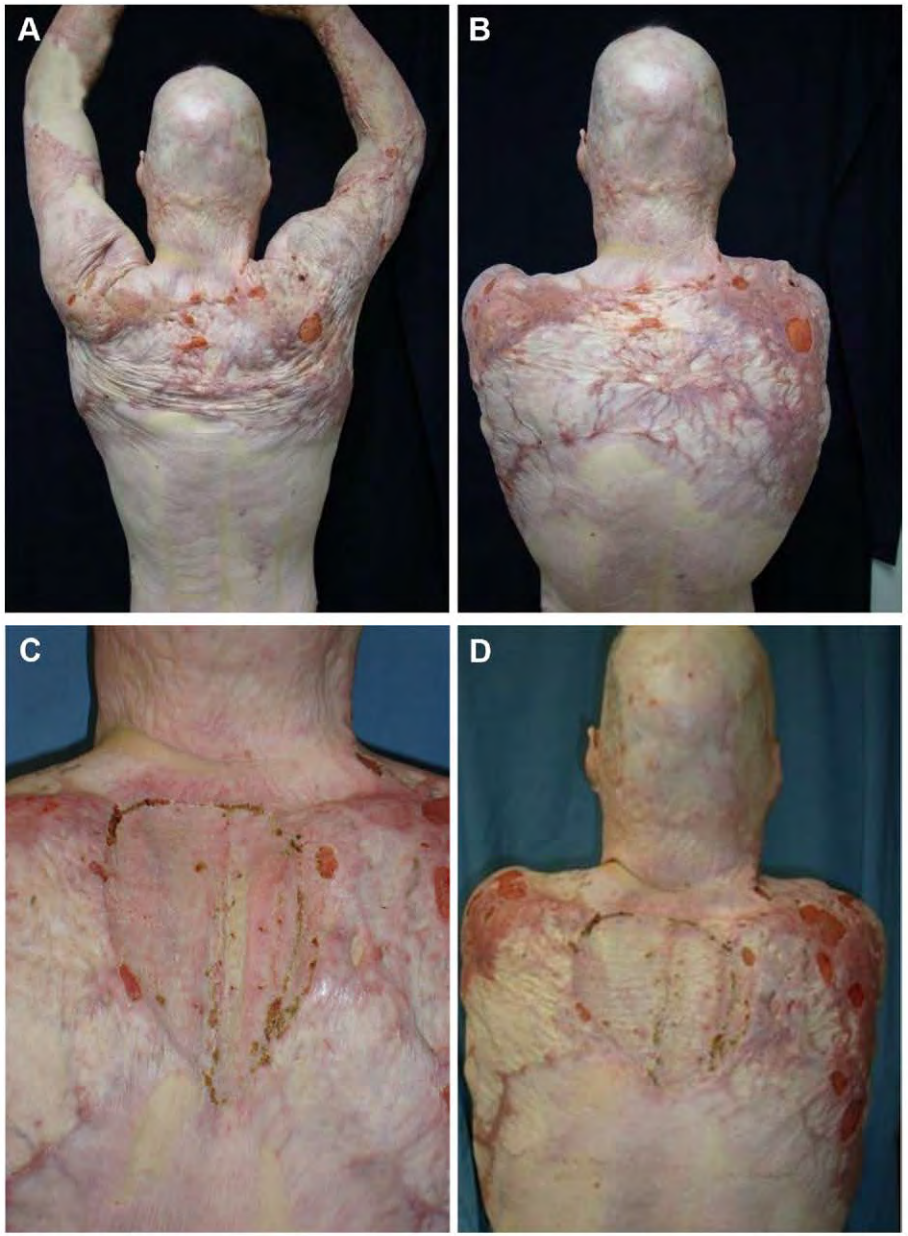

Fig. 3. In the same patient, linear scar release and grafting was performed on his back. His back contracture limits shoulder abduction despite correction of axillary contractures (*A*). Shoulder extension similarly results in recurring stress–relaxation of the scar (*B*). Linear contracture release without scar excision followed by grafting led to improvement of the tightness (*C*), especially with shoulder extension (*D*).

Pedicled and Free-Flap Closures

Flaps are chosen over grafts when the underlying wound bed cannot support a graft or when the possibility of recontracture not tolerated. Skin flaps are not vascularized by the wound bed, but carry their own blood supply. For that reason, they can be used to cover areas where graft loss is common because of movement or poor vascularity.[10] Local flaps are from adjacent areas, whereas distant flaps come from nonadjacent areas. A free microvascular flap, a type of a distant flap, involves microanastomoses of the donor and recipient arteries and veins. Flaps are very useful in burn resurfacing, but do have the disadvantages of being very bulky and often require additional revisional operations.

UNIQUE PERIOPERATIVE CONSIDERATIONS

Preoperative

An integrated approach to caring for a burn patient is of utmost importance. Facial scarring is incredibly visible and psychologically traumatic, creating some unique problems in providing care. The process must be flexible, and surgical plans can change, even preoperatively and sometimes intraoperatively. Because there is not often a single complete "fix," families and patients need reassurance from the burn team that although the process may require multiple operations and the course of treatment will very likely change with each procedure and its results, each operation moves toward the ultimate goal.[11] For patients undergoing autografts or flap transfers, preoperative education and discussion minimizes the unpleasantness of receiving yet another wound. Incorporating frequent updates helps to reduce the emotional turmoil inherent in reconstructive procedures.

Intraoperative

The duration of reconstructive operations varies depending on the selected procedure. Even with releases with or without grafting, reconstructive operations can become lengthy when performed on multiple sites. An appropriate amount of time must be taken to ensure the best possible outcome, especially when working with valuable and often limited donor tissue. Ensuring appropriate management of body temperature and fluids during the course of a prolonged operation is essential and can be significantly more complicated, even in burn reconstruction patients. In addition to the typical surgical concerns of padding, eye protection, and deep vein thrombosis prophylaxis, consideration and attention must be given to the increased possibility of positional changes and diminished quantities of soft tissue. Airway concerns must consider prior inhalation injury, late nasal or tracheal stenosis, and the possible addition of neck contracture and microstomia restricting airway access.

Postoperative

As with every step of the process, good communication is essential among staff members. Discussion with the operative team, patient, and family regarding procedures performed and postoperative care helps to ensure compliance and reconstructive success. Immobilization and rehabilitation after grafting are often crucial for success, but must be balanced between graft incorporation and prevention of joint contractures.[12]

SUMMARY

Although the operations required during acute burn hospitalization are life-saving, subsequent reconstructive operations can be life-giving. Each reconstructive plan is

tailored for each patient, depending on the specific deformity. Multiple reconstructive modalities are possible, but the goal is always restoration of form and function. The operative plan must include preoperative, intraoperative, and postoperative considerations to be successful.

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